ACCOMPLISHMENT REPORT

PROPULSION DIRECTORATE
October 1999

EUROPEAN AIRLINE STUDYING USE OF +100 ADDITIVE: KLM Royal Dutch Airlines is investigating the possibility of an international, commercial trial of the Air Force's +100 fuel additive. The +100 additive was developed by the Propulsion Directorate's Fuels Branch (AFRL/PRSF) in an effort to minimize maintenance costs associated with fuel degradation within aircraft fuel systems. Added to JP-8 (military) and Jet A (commercial) fuels, +100 has proven to be very effective in a number of military and commercial engine demonstrations. Anxious to reap the potential savings associated with using the additive, KLM has assembled a plan to fly two Boeing 747-300 aircraft with General Electric engines on fuel with the +100 additive to study its potential benefits for commercial aircraft. KLM has received the approval of Boeing and General Electric to use the additive in their aircraft and engines. Since KLM flies to many European countries, they are currently seeking approval of this test program from the Joint Aviation Authorities (JAA), the European equivalent to the Federal Aviation Administration (FAA). There is the potential that some of the flights may be to the United States, so FAA approval may be required as well. KLM is now examining some logistical issues such as how to inject the additive and which airports will need additive injection equipment. AFRL/PRSF has been asked to provide technical guidance to help answer some of these questions. It is hoped that all of the approvals, planning, and preparations can be completed by spring 2000 so the first international commercial flight of the +100 additive can take place in the year 2000. (P. Liberio, AFRL/PRSF, (937) 255-6918)

KLM 747-300

MINUTEMAN REAPS BENEFITS OF NEW MATERIALS: Low-cost materials developed under the Propulsion Directorate sponsored Missile Propulsion Components Evaluation (MPCE) project are having a dramatic impact on the Minuteman Propulsion Replacement Program (PRP). Under the Minuteman PRP, aged and environmentally unacceptable materials and components in Minuteman rocket motors are being identified and replaced. The motors are then refurbished for reuse in the Air Force's strategic missile inventory. Two materials developed by Thiokol Propulsion on the MPCE project are being transferred to the Minuteman PRP for use in the first stage motor. The new materials replace materials that are either too costly or no longer available. MXCE-69 replaces a material known as Travarno that is used to insulate the aft closure/nozzle entrance section of the Minuteman first stage

motor. Those familiar with the Minuteman program know this part as the "toilet seat." The cost of Travarno is $220/lb while the replacement material, MXCE-69, is only $60/lb, representing a savings of $160/lb. Each motor uses 320 pounds of this material, and 607 motors are in the plan to be refurbished; therefore, switching to the new "toilet seat" material represents a savings to the Air Force of more than $31 million! Remarkably, these savings were reaped from a program with an Air Force investment of only $1.2 million. The second MPCE material targeted for the Minuteman PRP is MX134-LDR, which replaces a rayon carbon phenolic used for structural overwrap since the original material is no longer available. (S. Bridges, AFRL/PRRM, (661) 275-5406)

PRATT & WHITNEY DEMONSTRATOR ENGINE COMPLETES TESTING: Testing of the Pratt & Whitney (P&W) XTE66 Joint Technology Demonstrator Engine (JTDE) was completed on 7 September 1999. This JTDE was P&W's final demonstration in Phase II of the DoD/NASA/Industry Integrated High Performance Turbine Engine Technology (IHPTET) Program. A total of 71.7 hours of testing were logged on XTE66, and the successes from the testing were many. Among the successes was P&W's first demonstration of a vaneless counter rotating low-pressure turbine (LPT). A "dipstick" damper was designed into the vaneless first stage LPT blade, and damper performance substantially exceeded pretest predictions by reducing blade vibratory stresses more than 80 percent. This result will have a profound effect on how high cycle fatigue (HCF) is dealt with in the Joint Strike Fighter (JSF). Furthermore, the turbine rotor inlet temperature (TRIT) achieved in the test exceeded goal levels by more than 10 percent. The ceramic matrix composite (CMC) interstage shroud in the turbine section also performed flawlessly. Overall, performance of the engine was very close to predicted levels. While the microwave augmentor test was unable to light and sustain combustion in the engine environment, prior sector rig testing was successful. Efforts will be intensified to understand the test data and to mitigate any risk associated with future microwave augmentor designs. A next generation design will be tested on P&W's initial IHPTET Phase III JTDE (XTE67/1) currently scheduled for spring 2001. (Capt. A. Cerminaro, AFRL/PRTP, (937) 255-2767)

PROGRESS ON INTEGRATED POWER UNIT DEMONSTRATOR: On 28 September 1999, personnel from the Propulsion Directorate's Power Generation (AFRL/PRPG) and Lubrication (AFRL/PRSL) Branches attended a progress meeting at Hamilton Sundstrand for the Integrated Power Unit Advanced Development Program. Under this program, Hamilton Sundstrand is demonstrating a unique gas turbine engine-driven electric starter/generator (rated at 125/200 kW, 270 Vdc, 60 krpm speed) which operates without any oil lubrication. Using an actively controlled magnetic bearing rotor support system eliminates the oil lubrication system and the associated rolling element bearings. The development program has progressed to the component hardware integration and subsystem demonstration phase and recently completed a significant technical milestone by achieving static levitation of a solid rotor. The rotor and its housing were also subjected to several impact tests to demonstrate the magnetic bearing's control system response and stability. The control system will be further optimized before rotational tests begin with the laminated rotor stack of the switched reluctance machine (SRM). It is expected that the two planned subsystem tests (i.e., SRM test and rotor/bearing test) will start and complete in the second quarter of FY2000, with the initial build of the demonstrator also beginning in the second quarter. (J. Tschantz, AFRL/PRPG, (937) 255-6241)

IN-HOUSE PULSED DETONATION ENGINE RUNS ON FIRST HOT-FIRING: Shortly after opening the fuel valve for the first time on 9 September 1999, the Propulsion Directorate's in-house pulsed detonation engine (PDE) fired successfully. The PDE is an advanced engine concept that holds the promise of outstanding propulsion performance from an engine that is relatively simple and cheap to manufacture. The research PDE was designed by Dr. Fred Schauer of the Combustion Branch (AFRL/PRSC) and constructed in-house. The research PDE has several unique features including pre-mixed operation, extremely broad frequency operating range, flexible tube configurations, and extremely low cost. The control system for the research PDE was designed and written in-house and performs all of the facility and engine controls and data acquisition simultaneously. The development of this in-house PDE facility signifies the rebirth of the formerly mothballed engine test cell, D-bay, which is on loan from the Turbine Engine Division (AFRL/PRT). The facility, which has been renamed the Pulsed Combustor/ Detonation Engine Test Facility, is capable of 10-60,000 lb_f thrust measurements, air and fuel flow measurements, and conventional pressure and temperature measurements, as well as high frequency data acquisition (such as the pressure measurements used for the current experiments). To date, runs of up to 91 seconds in duration have been made with this innovative engine concept. The in-house PDE will be used to verify performance prediction models and as a test-bed for research and development of this potentially revolutionary propulsion technology. (F. Schauer, AFRL/PRSC, (937) 255-6462)

PDE firing on 9 September 1999

X-33 TEST FACILITY COMPLETE: The Propulsion Directorate and its facilities at Edwards AFB, California, are providing infrastructure support to the Air Force Flight Test Center's Access to Space Office. The overall Air Force effort will support Lockheed Martin Skunk Works in launching the X-33 Reusable Launch Vehicle (RLV) technology demonstrator from Edwards AFB. The $20 million X-33 RLV technology demonstrator launch site has been built on 50 acres of Air Force land adjacent to the directorate's Test Area 1-56 where the launch control center is located. Completed just over a year from the groundbreaking, the facility is ready to receive the launch vehicle when Lockheed Martin Skunk Works and NASA have completed component testing and manufacturing of the X-33. The main propulsion for the X-33 is provided by the innovative aerospike rocket engine, which is derived from a concept developed at the lab more than 30 years ago. Boeing-Rocketdyne completed and modified the concept and proposed it for use with the Space Shuttle, and while not used for the Shuttle, the aerospike engine was not forgotten. By the summer of 2000, the X-33 may rise above Edwards AFB on its initial flight to Utah. If all goes well, the RLV will be returned for more flights from the launch site and pave the way for larger craft like the Venturestar. (L. Quinn, AFRL/PRR, (661) 275-5630)

The X-33 test site at Edwards AFB

The X-33 Reusable Launch Vehicle

NEW VALVE ENHANCES SAFETY, SAVES MONEY: Personnel in the Propulsion Directorate's Turbine Engine Research Center (TERC) have added a significant enhancement to the operation of the Turbine Research Facility (TRF). The enhancement to the TRF, which is located at Wright-Patterson AFB, Ohio, is an upgrade of the main valve. The main valve is a critical element of the TRF testing sequence that starts and stops the flow of gas to the turbine while under test. The previous main valve setup had many operational drawbacks. The old valve had a high operational overhead resulting from the dumping of about 3,500 cubic feet of test gas per day. Furthermore, the old valve experienced difficulty in sealing that created a potential safety hazard. The replacement system uses a hydraulic controller which allows a detailed tailoring of the opening and closing profile. This new system has the ability to open the 500-pound main valve 10 inches from a stand still and bring it to a complete stop in 0.175 seconds. In addition, a positive seal can be guaranteed due to the full positional control of the new system. Through this upgrade, efficiency and safety of TRF operations will increase, and significant quantities of expensive test gas, and therefore funds, will be saved. (D. Hoying, AFRL/PRTE, (937) 255-6802)

The new main valve installed in the TRF

LITHIUM-ION BATTERIES FOR SPACE TOOLS: The Propulsion Directorate's Battery Branch (AFRL/PRPB), under the Lithium-Ion Battery Development Program, has managed a team that is focused on putting the first American-made lithium-ion battery into space. The first scheduled use for this battery type is a December 1999 Space Shuttle flight. On this flight, a lithium-ion battery will provide power to a ratchet tool used for repairing the Hubble Space Telescope. Ultimately, a lithium-ion battery will also provide power to the Shuttle

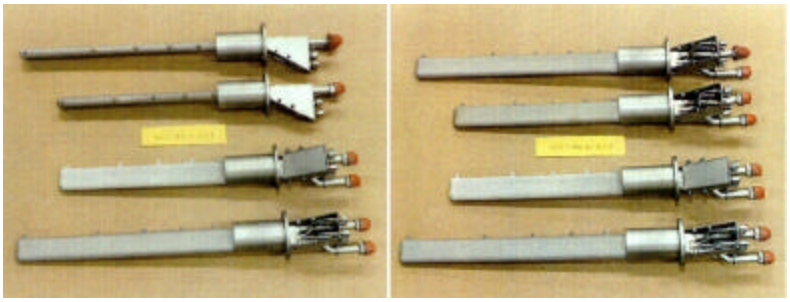
Pistol Grip Tool (PGT). The PGT is a self-contained, microprocessor controlled, hand-held tool designed for use by astronauts during extra-vehicular activities. The Government/Industry team making this possible includes representatives of PRPB, NASA Goddard Space Flight Center, NASA Johnson Space Center, Orbital Sciences Corp, and SAFT America. (S. Vukson, AFRL/PRPB, (937) 255-7770)

FURTHER REFINEMENT OF THE TRAPPED VORTEX COMBUSTOR: The Trapped Vortex Combustor (TVC) is a unique turbine engine combustor concept that offers reduced emissions and improved performance in a small, simple, low cost package. The TVC has already proven to be a great advancement in combustor technology. Now, General Electric Aircraft Engines (GEAE) and the Propulsion Directorate's Combustion Branch (AFRL/PRSC) are continuing their joint project to develop the TVC with an eye toward refinement of the concept. GEAE and AFRL/PRSC are in the midst of redesigning the integrated diffuser injector flameholder (IDIF) for the TVC. The IDIF supplies the main air and fuel flows to the combustor. The current IDIF and fuel injection system, although performing well, can be enhanced significantly, yielding further reductions in NO_x and better combustion efficiency over a wider fuel-to-air ratio range. The Universal Dome, or new IDIF, will most likely be either a perforated plate of AFRL design or a swirl-cup diffuser of GEAE design. Both designs will be evaluated in AFRL/PRSC's in-house facilities. AFRL/PRSC will be designing a set of diffuser plates with different arrangements of fuel and air injection to be evaluated in both the atmospheric-pressure and high-pressure combustion facilities over the next two years. (Capt I. Vihinen, AFRL/PRSC, (937) 255-8623)

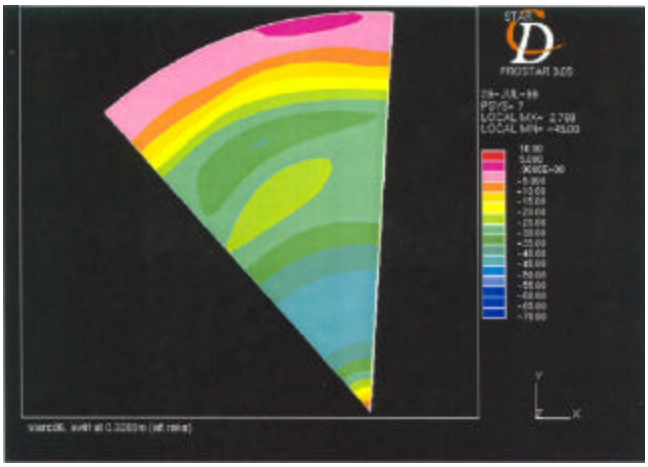
HAZARDOUS FUEL DISPOSAL SAFELY COMPLETED: Disposal of the Air Force's supply of pentaborane was successfully completed at the Propulsion Directorate's facilities at Edwards AFB, California, on 30 August 1999. Pentaborane (B_5H_9) was developed in the 1950s as a potential advanced aircraft fuel. The anticipated potential of this fuel was never realized, and when efforts on pentaborane were discontinued, a large quantity of the hazardous substance remained. As a result, 400 cylinders of pentaborane, each containing 500 pounds of the substance, were stored for more than 30 years at Edwards AFB. In recent years, it was determined that the stored pentaborane had no useful purpose. Furthermore, the storage containers were nearing the end of their practical life, and the supply of pentaborane posed a hazard to base personnel and local communities. Therefore, it was decided that the fuel should be destroyed. The disposal of the fuel was no trivial matter, and prior attempts by other organizations to dispose of small quantities of pentaborane had resulted in injury and death. It was determined that opening the cylinders with shaped explosive charges and, hence, igniting the fuel was the safest and most complete method of destruction. The plan to destroy the pentaborane was carefully coordinated with regulators, contractors, lab personnel, and local communities, and the destruction program proceeded without incident and resulted in a no-injury operational safety record. (L. Quinn, AFRL/PRR, (661) 275-5630)
[see Air Force news releases on this topic at http://www.ple.af.mil/press/articles/pentaborane1.html & http://www.ple.af.mil/press/articles/pentaborane2.html]

MORE AFFORDABLE EXHAUST SYSTEM: The Propulsion Directorate's "Augmentor for Affordable Exhaust System" Program with General Electric Aircraft Engines (GEAE) is progressing in

efforts to reduce engine development costs. The objective of this program is to develop an aerothermodynamic database for a swirl augmentor with a fixed nozzle geometry. By eliminating the need for a variable exhaust nozzle, this augmentor design significantly reduces the weight (-59 percent) and cost (-49 percent) of the exhaust system and contributes to the achievement of the engine thrust-to-weight goal (+185 percent). To date, the program has achieved two major milestones: (1) completion of a series of cold flow tests, and (2) fabrication of a pair of traversing, gas-sampling probes. The cold flow tests were run in a scaled model of the Phase II augmentor and fixed nozzle, and flow distributions and velocities of the core and bypass gas streams were mapped. This data is being used to calibrate the STAR-CD code which in turn will be used to make pretest performance predictions for the Phase II (XTE76-1A/-1B) augmentor and fixed nozzle. Actual performance figures will be obtained by measuring the augmentor's gas temperatures and emissions during an engine test. If successful, this will be the first case of a CFD code being validated using real engine data. The key to success is the gas sampling probes, which were designed to match the local flow angles so as to minimize the disruption to the local flow conditions. Careful consideration was given to enabling the probes to survive the hostile combustion zone without compromising data quality. It is hoped that this database and the associated CFD model will facilitate future development efforts by decreasing the dependence on expensive hot rig tests. (R. Sikorski, AFRL/PRTC, (937) 255-5974)



Some of the traversing rakes developed under the program



CFD solution showing swirl at the aft rake station

OSCILLATING HEAT PIPE FOR ACTUATOR COOLING: One approach employed for the cooling of aircraft electro-mechanical actuators (EMA) is to use passive reflux coolers, or thermosyphons, to transfer heat from the motor housing to the aircraft skin. This approach has several weaknesses such as the detrimental effects of the g-forces, ineffective use of required condenser area that integrates with the aircraft skin, poor mass-to-volume ratio, and slow thermal response. To overcome the above weaknesses, an alternate design for actuator cooling that uses a new oscillating heat pipe (OHP) concept has been initiated at the Propulsion Directorate's thermal management laboratory (AFRL/PRPG). The OHP uses self-excited oscillation movement of two-phase flow within a closed loop to transport energy from the evaporator to the condenser. A proof-of-concept OHP design was based on a 25-kW actuator operable from -54°C to 46°C with a nominal heat load of 2 kW. The OHP was fabricated by an on-site contractor team (UES), and after finishing data instrumentation and safety certification in June 1999, the OHP test unit has since undergone several initial performance tests. The OHP is specifically sized at 18"x12"x2" for a particular aircraft application, with 40 turns of 1/8" copper tubing. The transport fluid (acetone) has successfully transferred 2 kW of heat without any dry out. The flexible arrangement of the bent tubing lends itself to conformal installation onto various aerodynamic surfaces. When completed, this research could yield valuable data on an attractive option for actuator cooling. (R. Ponnappan, AFRL/PRPG, (937) 255-2922)

ARMY AND USAF TEAM QUALIFYING HELICOPTER ENGINES FOR JP-8+100: The Propulsion Directorate's Fuels Branch (AFRL/PRSF) is conducting a field demonstration of JP-8+100 in rotary-winged aircraft at Kirtland AFB, New Mexico. This demonstration program is examining engines used to power a number of different helicopters including the UH-1N, MH-53J, TH-53A, and HH-60. After learning of the Air Force demonstration program, the Army expressed a desire to qualify their aircraft for use on JP-8+100. They requested to be involved in the final Aircraft Component Inspection (ACI) of a T700 engine, the powerplant for the HH-60. The Army is particularly interested in this demonstration as they can qualify an engine without having to conduct an extended test since the Air Force has already executed the tests. If this engine qualifies for use on JP-8+100, then the Army believes a majority of their assets can be converted to JP-8+100. While maintenance records have not yet been examined for the T700 engines at Kirtland to determine any effects of JP-8+100 on engine maintenance, visual inspections of the T700 engines have shown them to be remarkably clean and coke-free. The Army has indicated that their major problem with the T700 engine is coking of the combustor fuel nozzle, and visual inspections at Kirtland have shown that coking in the T700s is virtually non-existent. This program, which commenced in May 1997, is scheduled to be

From top to bottom: the UH-1N, MH-53J, and HH-60 helicopters

completed in November 1999. (R. Morris Jr., AFRL/PRSF, (937) 255-3527)

SUPPORT CONTRACT AWARDED FOR ROCKET RESEARCH FACILITIES: On 7 September 1999, Sverdrup Technology was named the winner of the on-site Research Operation Support Services (ROSS) contract for the Propulsion Directorate's research facilities at Edwards AFB, California. The contract spans the next 5 years with two extension options that could potentially yield a 10-year contract valued at approximately $120 million. Sverdrup Technology, a subsidiary of Jacobs Engineering of Pasadena, California, has held the support contract since November of 1995. Their current manning of 140 personnel perform facility modifications, test operations, operational support, and maintenance efforts at the site, which serves the rocket propulsion efforts of the Air Force and the nation. The 65-square-mile facility has two-thirds of the nation's high thrust static rocket test stands and is considered a full spectrum lab, with the capability of supporting research for ballistic and heavy lift propulsion as well as tactical and space propulsion. Leadership for the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) Program, a 15-year effort to double rocket propulsion capabilities, is located at Edwards AFB. In addition, the site hosts Titan IV Solid Rocket Booster testing, Boeing-Rocketdyne's RS-68 liquid rocket engine testing, and the X-33 Reusable Launch Vehicle (RLV) Technology Demonstrator launch site. Technologies developed at Edwards AFB are found in virtually every military, civil, and commercial launch and satellite propulsion system. (L. Quinn, AFRL/PRR, (661) 275-5630)
[see the Air Force News Release at http://www.ple.af.mil/press/articles/Svertech.html]

Test Stand 1-C, the site of Titan IV testing

Test Stand 1-A, the host of RS-68 testing